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# Mine Health and Safety In-House Research, Development, and Demonstration in Fiscal Year 1979

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United States Bureau of Mines

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# Mine Health and Safety In-House Research, Development, and Demonstration in Fiscal Year 1979

By Staff, Division of Mining Research—Health and Safety

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

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# MINE HEALTH AND SAFETY IN-HOUSE RESEARCH, DEVELOPMENT, AND DEMONSTRATION IN FISCAL YEAR 1979

by

Staff, Division of Mining Research—Health and Safety


## ABSTRACT

This publication summarizes, for all interested parties, the research, development, and demonstration in-house projects programed by the Bureau of Mines for fiscal year 1979 (October 1, 1978--September 30, 1979) under its Mine Health and Safety Research program. The objective of these projects is to provide an ordered and sequenced series of advances toward the Bureau's overall goal of providing the system technology required to create a healthier and safer working environment for the Nation's miners.


## INTRODUCTION

The Bureau of Mines conducts a balanced, continuing in-house research and development program to accelerate systematic improvements in health and safety conditions in U.S. mines. This paper outlines the Bureau's present in-house research effort to all interested parties; in particular, potential contractors can refer to it when submitting USP's (unsolicited proposals), thus avoiding proposing research that duplicates work being performed by the Bureau.

The projects presented were planned at the beginning of the fiscal year and are subject to change based on emerging priorities and availability of funds. A companion publication, Information Circular 8797, lists contract projects.

## PROGRAM OUTLINE

The objective of the Mine Health and Safety Research program is to protect the health and safety of mine workers while insuring that newly developed mining technology incorporates health and safety criteria. In achieving this objective, four fundamental and complementary requirements must be considered by the research program, as follows:

1. Contributing to the viability of a basic industry.

2. Sustaining productivity.

3. Allowing for a return on capital investment.

4. Providing material and energy to the public.

Since mining involves a highly integrated and interrelated set of functions, the program has been divided into a set of interrelated subprograms, each with goals that will provide systems technology solutions to the problems within the framework of these fundamental requirements. The Mine Health and Safety Research program is divided into 12 subprogram areas as shown:

| Health | Safety |
|---|---|
| Respirable dust | Fire and explosion prevention |
| Radiation hazards | Methane control |
| Noise control | Ground control |
| Industrial hygiene | Industrial-type hazards |
| Ventilation | Postdisaster |
| | Systems engineering |
| | Explosives |

The objectives of these subprograms are described in the following pages, followed by the planned projects and their corresponding descriptions. The aggregate value of the planned in-house projects is approximately $14 million.

## HEALTH

### Respirable Dust

Program Objectives: To develop procedures for controlling the respirable mine dusts that still constitute the severest health problem facing the mining industries. To develop and/or improve techniques and equipment to prevent formation of hazardous dust concentrations, and to protect miners against dusty atmospheres.

#### Fundamental Studies

1. Aerodynamics of Dust at the Mine Face

Objective: To provide engineering guidance for the development of a longwall shearer with improved dust control. Laboratory-scale monitoring will be used to investigate the effect of air intake location on the efficiency of a secondary exhaust ventilation system mounted on a longwall shearer. The data will be presented in written technical reports for use by the Mine Safety and Health Administration (MSHA) and industry in developing improved dust control technology.

## Fragmentation Control

2. Reduction of Airborne Coal Dust and Increased Machine Efficiency

Objective: To develop background information in support of contract research related to reduction of primary dust generation at the bit-coal interface during cutting. The major task will be a series of tests designed to determine the effects of water lubricity at the bit-coal interface on primary dust generation and cutting forces. A further task will be field testing of the retrofit microminer. This may include measurement of sump-shear forces for both point attack and chisel-type bits in different coal types on both face and butt cleats. Additionally, coal fracture noise data will be obtained by operating off accumulators only.

## Control of Generated Dust

3. Control of Respirable Dust by Water Infusion and Other Means of Preconditioning

Objective: To conduct underground evaluations to determine the effectiveness of water infusion for respirable dust control. Particular attention will be given to longwall mining operations in different coal seams. Work will also include evaluation of the physical properties of the coalbed relating to water flow. These properties include infusion pressure, water flow rate, fracture permeability, and porosity.

4. Evaluate Dust Control Techniques at and Outby the Coal Face

Objective: To conduct fieldwork to determine the dust reduction at continuous-mining machines versus various engineering parameters; for example, the reduction obtained with different water sprays. Work will also include investigation of secondary ventilation on longwall shearers and continuous miners with machine-mounted dust collectors. The degree of dust reduction at belt transfer points that is achieved with different water sprays will be studied. A laboratory study of air entrainment and dust capture efficiency by conventional and eductor nozzles will be continued.

5. Dust Control by Water Sprays

Objective: To study high-pressure shrouded water sprays by testing candidate configurations suitable for a ripper mining machine and also other mining machines. Several candidate configurations will be tested on the full-scale mockup of a ripper machine to investigate interaction between the main ventilation airstream and the effect of the cubic feet per minute of the secondary airstream. The capture efficiency of the secondary air intakes and the dust collection efficiency of the shrouded sprays will be studied.

6. Dust Suppression for Haulage

Objective: To determine the effectiveness of various wetting agents for different types of coals obtained from seams throughout the country. Over

100 surfactants have been obtained from about 40 different companies. The wetting effectiveness of these surfactants will be determined for 100 different coal samples obtained by MSHA personnel from seams throughout the country. The information and data obtained from the proposed program will result in more effective and economical use of wetting agents in reducing respirable dust.

7. Dust Control Technology

Objective: To establish new or improved dust control techniques for metal and nonmetal mining and milling operations. The dust control needs of industry will continue to be evaluated through visits to various mine and mill sites. As part of this task, a small effort will be devoted to clarifying the aerodynamic behavior of the "lacy" agglomerates of diesel particulate (cascade impactor, field sampling, scanning electron microscope observation) and to determining the effectiveness of cab filtration systems for controlling respirable dust inside the cab. Improved and new dust control techniques will be developed for mining operations involving soluble ores and for the Dosco-Alphine type of mining machine. The control techniques already developed for silica baggers will be transferred to other industries.

## Analytical Techniques and Equipment

8. Respirable Dust Measurement Instrumentation Evaluation

Objective: To evaluate dust samplers and monitors developed by Bureau contractors and others, both in the laboratory and in mines. Specific instruments to be evaluated include the machine-mounted dust monitors using beta-attenuation, the improved light-scattering dust monitors, the GCA fiber aerosol monitor, and the coal mine personal samplers.

## Radiation Hazards

Program Objectives: To develop and provide new and improved measurement instrumentation and control technology for protection of miners from exposure to radon and radon daughters and other nuclear radiation hazards in uranium mines.

## Fundamental Studies

1. Effect of Stress on Radon Emanation and Transport

Objective: To conduct necessary laboratory experiments to determine the effect of stress induced by mining on radon emanation and transport, and to attempt to measure total surface area of the rock, including surface area of microfissures and other surface deformities, and correlate these data with radon emanation coefficients.

## Control of Radon and Radon Daughters

2. Improved Bulkhead Design To Reduce Radon Leakage From Worked-Out Areas

Objective: To conduct laboratory and field evaluation of existing and modified bulkhead designs to determine the most effective design and construction techniques and use of construction materials to reduce radon leakage into the ventilation system of a uranium mine. The following control techniques will be studied to determine the conditions that will result in minimum leakage from bulkheaded areas: (1) Reducing pressure behind the bulkhead, (2) maintaining pressure behind the bulkhead at quasiequilibrium with the surface through a breather pipe, (3) using better sealant materials, and (4) chemical grouting. The collection of design, construction, bulkhead material, and performance data for a "how-to" handbook will continue, and a cost-benefit analysis will be performed on each bulkhead design.

3. Radiation Control of Tailings Backfill in Uranium Mines

Objective: To field-test developed techniques for controlling radon emanation from uranium mill tailings used as backfill. The most effective stabilization, sealing, and bulkhead design technique for minimum radon emanation will be determined.

4. Control of Radon Daughters Through Air Cleaning

Objective: To continue research on the use of air-cleaning techniques for removal of radon daughters from underground mine atmospheres. Efficiencies, filter life with regard to moisture and airborne particle size, and concentration and characteristics of the radioactive component of the filtered air will be determined. Necessary technical assistance will be provided to the contractor during development and testing phase of a prototype air-cleaning system. The results achieved to date will be documented in a report suitable for use by the mining and air-cleaning industry.

## Radiation Instrumentation and Measurement

5. Electronic Radon Daughter Personal Dosimeter

Objective: To continue development of a small, solid-state instrument that will record the daily working level-hour exposure of a miner exposed to radon daughter contamination. Laboratory and field-testing of a modified dosimeter will be conducted, and technical support will be provided during the field study. Field data will be reviewed and analyzed. Investigation of new pumps in the laboratory and field will be continued. The feasibility of using a new detector in lieu of current types will be investigated, and the research required to introduce such a detector into the current dosimeter system will be determined.

6. Personal Exposure Instrumentation and Measurement Research

Objective: To continue laboratory and field studies of personal dosimeters for the measurement of working exposure. Assistance will be provided during field testing of dosimeters to verify previously established accuracy of instruments under test. Evaluation of new dosimeter components as they are made available will continue to assist in improving the accuracy and reliability of the current threshold-level dosimeter system. The accuracy of the alpha alarm and research needed to make it a reliable device will be determined. Instrumentation and methods of measuring the uncombined fraction of daughter products will be investigated.

7. Radiation Warning Systems

Objective: To develop and demonstrate an automated warning system that alerts mine personnel to excessively high concentrations of airborne radiation in selected areas. The design will incorporate simplicity, reliability, low cost, standardization of components, interchangeability, and the capability of being mated with other warning systems under development to produce a complete minewide system. Appropriate drawings will be developed in accordance with established American National Standards Institute standards suitable for use by any instrument manufacturer.

## Test Facilities

8. Lease and Operate the Twilight Mine

Objective: To continue to operate and maintain an underground uranium mine as a test facility to provide typical mine environmental conditions for research and development studies conducted by the Bureau of Mines, MSHA, other Government agencies, and outside contractors in the area of radiation hazards.

## Noise Control

Program Objectives: To identify noise sources in underground and surface mines and in related surface facilities, to abate these noise sources sufficiently to meet noise exposure standards, and to evaluate a personal time-resolved audio dosimeter.

### Assessment of Noise Control Techniques for Coal Mining Machinery

Objective: To continue work on abatement of noise from pneumatic rock drills through development of shielding and damping techniques for drill steel. A quiet preproduction stoper drill to be delivered under contract will be evaluated. Work on quieting the Jeffrey 100-L auger cutterhead will be initiated and will involve field evaluation. New emphasis will be placed on transferring the results of successful noise control research projects to MSHA and the mining industry.

## Industrial Hygiene

Program Objectives: To identify and control the health hazards created in underground mines by toxic gases and fumes, and by certain particulates produced by explosives and combustibles and by diesel engines. To develop new instrumentation for monitoring toxic components of the underground environment and evaluate commercially available instrumentation, to develop and/or refine analytical techniques for characterizing and measuring toxic components, and to investigate methods for controlling the formation and accumulation of toxic products.

### Toxic Gases and Materials

1. Toxic Fumes From Explosives

Objective: To develop, improve, and apply methods of measuring toxic fumes produced by explosives used in underground mining. Different types of commercial mining explosives and new formulations designed to study how toxic fumes may be decreased will be evaluated. In addition, procedures will be established for the measurement of suspected toxic gases from explosives and blasting agents (other than those toxic products currently being measured for the purpose of fume classification). Eventually, the research should lead to the perfection and semiautomation of test procedures and the establishment of new standards for fume measurement, as well as new fume standards for underground mines.

2. Develop and Evaluate Detectors for Noxious Gases

Objective: To evaluate and verify the performance of commercially available and contract-developed dosimeters for toxic gases. A small colorimetric dosimeter is currently under development. The readout efficiency of the device will be improved. As required, evaluations of commercial devices will be made. Testing will be done with temperature, relative humidity, and interferent gases as variables.

### Diesels

3. Development of Alarm Systems for Engines Operated Underground

Objective: To provide increased safety to the diesel vehicle operator through continuous monitoring of ambient $CO_2$ levels on board the vehicle by having a warning indication at moderate levels and an automatic vehicle shutdown if an unacceptable level is sustained. Field tests on about 20 alarms from Beckman and/or Andros have been initiated and will continue under Bureau and MSHA supervision.

4. Investigation of Emission Controls for Large Turbocharged Diesel Engines Operated Underground

Objective: To determine the potentially feasible methods and hardware available and applicable for use as emission and temperature controls on

turbocharged diesel engines. The work will begin with a literature search through technical society publications and computerized information retrieval centers. Experts in appropriate fields of the automotive industry, diesel engine manufacturing, mine equipment manufacturing, MSHA, and the Environmental Protection Agency will be contacted. Methods and hardware will be determined.

5. Control of Diesel Exhaust Contaminants

Objective: To determine the effectiveness of absorbents, catalysts, and a scrubber in reducing levels of contaminants, to facilitate mine usage of diesels. Emission levels will be related to ambient levels of toxicants in a mine. Single and tandem controls will be used to reduce the levels of particulates and other contaminants. Appropriate analytical methods will be selected for acrolein, sulfates, and other toxicants that are difficult to analyze.

## Ventilation

Program Objectives: To apply ventilation technology previously developed for underground coal mines in metal and nonmetal mines; to expand and/or adapt such technology to meet special requirements of noncoal mines.

### Development of Improved Ventilation Technology for Noncoal Mines

Objective: To continue to measure trace methane concentration in noncoal mines to assess the hazard. Inmine tests will be conducted to determine the effectiveness of a chilled-water-spray system in lowering the temperatures in working areas. Inmine tests of the parachute-type stopping will be completed to determine sealing efficiency, durability, blasting effects, problems, and overall usefulness.

## SAFETY

### Fire and Explosion Prevention

Program Objectives: To develop procedures to (1) eliminate ignition sources, such as frictional and electrical sparks, (2) prevent the formation of flammable atmospheres in underground mines, (3) detect fires and explosions at the earliest possible stage, and (4) provide effective physical and/or chemical means of arresting and quenching fires and explosions when their occurrence cannot be otherwise prevented.

### Ignition Research

1. Specifications for Intrinsically Safe Equipment

Objective: To increase the safety of intrinsically safe electrical equipment and to facilitate the approval and certification process. Denver and United Laboratories data will be evaluated and verified, and additional test methods will be developed. Proposed regulations by MSHA for the intrinsically safe certification will require the development or specification of new test methods and engineering data.

2. Spontaneous Heating of Coal Mine Combustibles

Objective: To investigate CO formation and the spontaneous heating hazard of U.S. coals and other mine combustibles, and to create criteria for detecting incipient mine fires. Emphasis of the laboratory work will be upon the variation of the oxygen absorption rate constant with the methane content of the coal, which is critical according to recent U.S.S.R. research. The laboratory-scale data will be compared with field experience data to determine the reliability of correlations based on the laboratory-scale data. The research should provide reliable guidelines for predicting and monitoring spontaneous combustion hazards during mining, transportation, or storage of coal. The data will be useful in reducing risk during mine fire recovery operations.

3. Coal Dust Ignition and Explosion

Objective: To eliminate or control coal mine dust explosions through a better understanding of the basic explosion process and the control that can be applied. Studies suggest that incandescent particles are important in ignition and propagation with even high-volatile coal dust; nonuniformities in the test vessel may limit small-scale severity. Understanding the mechanisms and control of coal mine dust explosions will increase safety and may permit pneumatic conveying.

4. Bit Impact Ignition of Methane

Objective: To relate methane ignition to bit wear and speeds, float dust, and ventilation circulation at the machine coal interface, and to develop optimum machine operating techniques to minimize or eliminate these ignitions. When wear-, speed-, and ignition-related conditions have been established in the first phase of the project, float dust will be added to the ignition test chamber, and ventilating airflow will be varied to determine any new effects on the preexisting conditions. Once these quantitative measurements of methane ignition probability are made, optimum prevention techniques will be recommended and guidelines will be available for maximum permissible wear patterns for a given velocity with a given ventilation rate for a specified float dust concentration.

Flame Propagation

5. Physical Description of a Coal Mine Explosion

Objective: To increase the understanding and predictability of the initiation, propagation, and suppression of explosions of gases and dusts in multientry mines. Explosion tests will continue to complete tasks left over from fiscal year 1978 and may include correlation of theoretical work on methane roof layers, explosions in beltways with barriers, limits of explosibility of coal dust-salt mixtures, and adaptation of the laser doppler anemometer to the measurement of ventilation flow and explosion flows. MSHA will benefit from this work by being able to modify or write new regulations on how to prevent or mitigate coal mine explosions. Stoppings and bulkheads may be designed and

applied with increased safety without excessive cost or decreased coal production.

6. Scale Study of Coal Mine Fires

Objective: To develop fire research techniques and instrumentation, evaluate fire extinguishment and smoke control techniques, and develop scaling criteria for relating data obtained in small- and large-scale coal mine fires. MSHA and the mining industry will use the criteria developed for the control of formation and spread of smoke, toxic fumes, and heat in underground coal mines. Techniques for optimum extinguishment of deep-seated and smoldering coal fires will greatly decrease the time required to put a mine back into operation after a fire and will increase the safety of the mine rescue operations.

7. Flammability of Coal Mine Combustibles

Objective: To develop improved laboratory-scale flammability tests to update MSHA schedule test methods, including Schedules 2G and 30 fire resistance tests. The laboratory test method developed in fiscal year 1978 for updating the Schedule 2G flammability test for conveyor belts will be subjected to final testing to demonstrate its reliability and reproductibility. Other work will include developing an improved Schedule 30 fire resistance test. The value of the minimum $O_2$ index test (ASTM D-2863) or other standard ASTM methods will be investigated as a screening test for mine combustibles.

8. Flammability of Uniformly Dispersed Dust

Objective: To study the flammability behavior of air-dispersed dusts in a new, improved laboratory-scale apparatus which provides for more accurate control of the significant experimental values. Data will be correlated with full-scale mine and gallery tests and integrated into a unified theoretical framework. Among the categories of proposed work will be (1) a search for an effective chemical inhibitor for coal dust, (2) a study of volatility and flammability effects of other dusts, (3) studies of flame temperatures, and (4) a study of the effects of varying $O_2$ content as well as a continuation of theoretical studies.

9. Explosion Hazards of Dust Layers

Objective: To develop a method for assessing the potential dust explosion hazards of accumulated layers in surface buildings. A methodology will be developed to aid inspectors in determining if a dust layer in preparation plants is sufficient to present an explosion hazard.

Fire Detection and Alarms

10. Evaluate Detection Systems for Fires and Explosions

Objective: To explore the problem of detecting mine fires and explosions; detect conditions that lead to such fires or explosions; evaluate and adapt

current sensors for mine use; design, develop, and build new detectors; and explore and evaluate new detection methodologies. Research and development activities will be designed to lead to detectors whose use in mines will improve safety and efficiency. Specifically, there will be evaluations of Somerset tube bundle installation and of the tube bundle method for shafts and belt haulageways. Also, an evaluation of ionization-attachment sensors in mine tests is planned. Testing of an infrared overheated roller sensor and development of a dust cloud monitor and a methane layer backscatter sensor are proposed.

11. Evaluate Fire Detection Systems

Objective: To demonstrate the reliability and sensitivity of a prototype fire detector for use in metal and nonmetal mines. The prototype incipient fire detector will be field-tested and evaluated in the laboratory. Evaluation of state-of-the-art fire detectors and detection methodologies will continue.

12. Physical Modeling of Mine Timber Fires

Objective: To develop scaling laws for full-scale mine timber fires from laboratory tunnel wood fire model studies, and to devise optimal methods for prevention and control of fires in horizontal and sloped roadways and vertical shafts. Work will continue at the tunnel fire and the solid combustion-pyrolysis laboratories in Bruceton. Areas of investigation will include criteria of ignition and spread of fire, effect of ignition source intensity on fire growth, flow interaction between fire and air ventilation, and effect of buoyancy on descensional and ascensional slope fires. The laser irradiation technique will be used to evaluate the importance of material parameters. Because timber is a major fuel in mine fires, particularly in metal and nonmetal mines, there is a need for improvement in prevention and control techniques that will provide MSHA with new guidelines for mine fire safety regulations.

## Suppression and Extinguishment

13. Mechanism of Methane Flame Suppression

Objective: To determine the physical and chemical processes occurring in inhibited methane flames by the techniques of flame microstructure analysis. Using the information, the effectiveness of chemcial flame inhibitors and extinguishing agents may be better understood. Experimental work to obtain the composition and temperature profiles of a HBr-inhibited methane flame will be completed, and data analysis will begin. Work will begin to determine the particulate temperatures at which powdered chemical extinguishing agents decompose to the gaseous states and to identify the species formed. A detailed understanding at the molecular level of the processes by which extinguishing agents operate will better define the performance capabilities of these retardants.

14. Improved Fire Protection Systems for Mining Equipment

Objective: To develop and inmine-test improved, reasonably priced, reliable fire protection hardware for surface and underground metal and nonmetal mines. General design criteria for the hardware that is to be fabricated and tested were generated by previous contracts and inmine work. More inmine testing is planned for improved (more rugged) fire sensors in underground mines.

15. Fire and Explosion Properties of Oil Shale

Objective: To further define, by means of large-scale tests in the Bruceton Experimental Mine, the explosibility limit of coarse oil shale dusts and fire spread rates of bulk materials. The limits of explosibility of coarse oil shale dust as a function of strength of ignition also will be determined. Oil shale rubble will be placed on the brick floor and ignited by a typical oil shale burn in the presence of ventilation. Vertical slabs will be used to simulate fire spreading to a wall.

16. Field Investigation of a Coal Mine Fire

Objective: To provide information on coal mine atmospheres during either the incipient stages of a fire or the extinguishment of a fire that has been sealed. As emergencies arise, attempts will be made to meet them. For example, in fiscal year 1977, mine-atmosphere-monitoring systems were set up by personnel in two mines; they were used as a warning system to mine personnel during a body recovery, as well as for valuable research experience. Warning of incipient combustion will be the major advance of the study, providing safety for recovery crews.

17. Sealed Coal Mine Fires

Objective: To develop the needed guidelines for the safe reopening of a mine, following the sealing of a coal mine fire. It is hoped that the large-scale fire trials in the multiple-entry Experimental Mine with 15- to 20-ton coal piles plus one oil shale burn will be completed this fiscal year. Benefits of the project will include improving the safety in reopening a sealed area of a mine and decreasing downtime to a minimum.

18. Passive and Triggered Barrier Systems

Objective: To develop and test passive and triggered barriers, which are to be reasonable prototypes for use in working mines for the suppression of coal dust explosions. Passive water barriers will be developed and tested in a double entry of the Bureau's Experimental Mine, using belt conveyors and stoppings in crosscuts to determine the effectiveness of barriers and optimum deployment. Triggered barriers will be tested against coal dust explosions under conditions simulating a longwall. Coal dust explosion suppression tests will be conducted in metal galleries using inhibitor dusts to determine flame temperature, product gas composition, and minimum temperature required for ignition of a coal dust cloud. Agreements with coal mine operators will be established to install prototype barrier units in working mines on a trial

basis. Barriers developed, tested, and found to be suitable will serve as prototypes for protection against explosions in working mines.

19. Improved Fire Protection Hardware Demonstration

Objective: To develop and inmine-test improved automatic fire protection hardware developed at the Twin Cities Mining Research Center. Monitoring of the automatic fire protection systems currently installed near Rock Springs, Wyo. (Northern Energy Resource's Jim Bridger mine) and near Pittsburg, Kans. (P & M's Empire mine) will continue. Different automatic fire protection devices utilizing hardware from other manufacturers will be installed and inmine-tested. The durability, reliability, and cost effectiveness of improved automatic fire protection hardware developed by the Bureau and by manufacturers will be determined.

## Gas Detection Instrumentation

20. Improved Portable Instruments for Measuring Methane and Other Gases

Objective: To provide gas detection device test facilities and personnel for performance evaluation of contract-developed hardware. The participation of project personnel in various design project literature reviews and in gas detection evaluation will give them experience for the generation of proposal requests, evaluations, and contract guidance. Specific tasks include (1) testing CO-indicating gels, (2) evaluating handheld NO, $NO_2$, and $CO_2$ detectors, (3) conducting laboratory and field trials of infrared methane toxic gases and airflow, and (4) providing technical assistance and evaluation of gas-monitoring systems under development.

21. Develop a High-Concentration Dust Meter

Objective: To develop a rapid, portable meter for measuring dust concentrations in surface and underground mines and in pneumatic duct transport systems to determine if the cloud concentration is explosive.

## Methane Control

Program Objectives: To prevent the formation of flammable methane-air mixtures in underground workings through improved ventilation and procedures for degasifying the coalbed in advance of and during mining. To establish correlations between the geology of the coalbed and its gas content and use these to predict methane emission hazards.

## Fundamental Factors

1. Influence of Geology on Occurrence and Emission of Methane in Coal Measures

Objective: To develop detailed geologic information for selected coalbeds to identify the factors that influence methane occurrence and emission. Mapping, collection of pertinent geologic data, and calculation of gas content

provide the information needed to predict the methane in a block of coal, the pressure under which it occurs, and factors governing its movement. With this information the ventilation requirements of the mine can be determined, and effective systems for methane control can be designed.

## Control in Advance of Mining

### 2. Application of Vertical Borehole Degasification to Mine Safety

Objective: To select sites, design the borehole patterns, and collect and analyze the data for specific demonstrations of methane drainage through vertical boreholes drilled into the coalbed ahead of mining.

### 3. Use of Large-Diameter Multiple-Purpose Borehole for Methane Control

Objective: To continue to monitor the methane emission from the multipurpose borehole and the in situ pressure and gas content at two boreholes between the multipurpose borehole and the nearest mine entries. As the entries are advanced toward the borehole, methane emission and coal productivity studies will be conducted underground to evaluate the effectiveness of degasification by the multipurpose borehole.

### 4. Use of Air Shafts for Degasification of Coalbeds in Advance of Mining

Objective: To demonstrate the utility and cost effectiveness of using long horizontal holes at the bottom of future air shafts to degasify large blocks of coal ahead of mining. The techniques will be demonstrated in a number of coalbeds having different characteristics. Holes at least 1,000 feet long will be drilled into the coalbed from the bottom of an air shaft that had been sunk at least 5 years ahead of active mining. Gas and water production from the holes will be monitored, and provisions will be made for recovering the gas. When mining toward the shaft is underway, face emissions of methane will be monitored.

## Control During Mining

### 5. Development of Control Techniques Using Horizontal Boreholes

Objective: To demonstrate the effectiveness of long horizontal boreholes drilled into the coalbed from underground locations to reduce methane levels during mining. Full-scale studies will be conducted in various coalbeds to demonstrate drilling procedures and methods of safely handling large volumes of methane. The effectiveness of natural drainage through these horizontal holes in reducing methane emission at the face during mining will be determined.

### 6. Study of Ventilation in Control of Methane

Objective: To develop ventilation technology to improve face ventilation, reduce stopping leakage, and provide better methods of measuring airflow where needed. Current emphasis is on assessment of ventilation of raise drill cavities, investigation of techniques for measuring low-velocity air, and evaluation of stopping sealants.

7. Study of Use of Water Infusion To Control Methane

Objective: To determine the feasibility of controlling methane emission at the face in various coalbeds by water infusion. Full-scale underground tests will be conducted in a working section of a mine to determine the effects on methane during mining. Physical properties of the coalbeds relating to waterflows will be evaluated.

8. Gob Degasification From Underground Locations

Objective: To develop cross-measure drilling techniques and determine optimum angle and length of holes to remove large volumes of methane from gob areas effectively from underground locations. A vacuum pump will draw methane from the gob through an underground pipeline and vertical borehole to the surface.

## Ground Control

Program Objective: To conceive, develop, demonstrate, and transfer technology that will present mining accidents attributable to falls of ground, outbursts, and slope failures.

### Premining Investigations

1. Delineation of Hazardous Geologic Structures in Coal Mines

Objective: To identify and map roof rock structures that contribute to roof failure in the Pittsburgh coal seam. Roof falls and related geologic features will be inspected, and the roof support methods used will be analyzed. Trend of the geologic features will be established to test local predictions. Reports on the geologic features and general guidelines will enable mine operators to assess roof conditions and hazardous zones. A hazard-rating system will be initiated for the seam, and the hazards-mapping information developed under contract will be coordinated into a uniform classification scheme.

2. Geologic and Engineering Data Acquisition for Underground Coal Mine Ground Control

Objective: To define requirements needed to establish a systematic repository of ground control data starting with a selected coal region. Included in the data will be physical properties of coalbed, roof, and floor strata, as well as pillar strengths, surface subsidence records, and roof support data. Utilizing the companion contract, a standardized format will be developed for data collection and retrieval. A program plan will outline procedures for obtaining data, and access system information will be developed into a users' guide.

3. Mining Applications of Integrated High-Resolution Seismic and Acoustic Reflection Techniques

Objective: To develop surface seismic and acoustic reflection techniques to provide a core geophysical approach to the channel sands, geologic faults, and abandoned mine workings detection problem. Field tests will be performed to characterize ground conditions, to optimize capabilities of the equipment, to develop rapid field operation procedures, and to provide a data base for the development of rapid data analysis procedures. Project emphasis will be on delineating abandoned mine workings with acoustic and three-dimensional seismic techniques. The resolution capabilities of the system will be improved to allow for detection of coal seam interfaces. Specific geologic hazards will be correlated with mining problems, the cost-benefit parameters of detection techniques will be established, and methodology for the hazards identification techniques will be described.

4. Humidity Effects on Roof Stability

Objective: To determine the overall influence of atmospheric humidity on the occurrence of roof falls in U.S. underground mines. The severity of the humidity problem in each of the major mining provinces will be defined. Roof fall and humidity data will be compiled and reduced to usable form, and analyses to detect correlations between atmospheric humidity and coal mine roof falls will be initiated.

5. Geophysics To Delineate the Zone of Weakened Rock Underlying Surface Bodies of Water

Objective: To develop a procedure for delineating the zones of weakness underlying bodies of surface water. Potential test sites that are underlain by coal mines will be evaluated. A field test will be conducted and related to geologic conditions, and a plan will be developed for an extensive contract program of research to demonstrate a practical approach to ground character definition.

6. Acoustic and Electromagnetic Properties of Coal Measure Rocks

Objective: To determine acoustic and electromagnetic properties of coal measure rock for the major U.S. seams for the interpretation of field geophysical data. Cores will be obtained, and property measurements will include compressional wave velocities, anisotropism factors, attenuation factors, and elastic moduli. These data will be correlated with in situ data to determine scaling relationships. Electromagnetic properties will be tested and related to natural ground conditions. A fiscal year report will outline all acoustic and electromagnetic property data, current investigations, and plans for application of the data to existing Bureau and industry geophysical system interpretation methods.

7. Delineation of Abandoned Mine Workings With Microwave Techniques

Objective: To develop and refine ground radar, microwave, and sounding techniques; and to detect and delineate abandoned mine workings, voids, etc., in metal and nonmetal mining areas. Field tests will be made on the focused antenna, design criteria will be established, and second-generation antenna development will be initiated. Field tests will be conducted in open pit and underground mines to determine application of limits of equipment. FM/CW radar will be compared with pulse radar to determine the most accurate and adaptable system for metal and nonmetal mine void detection. Guidelines will be developed for equipment applications by operators and for standards promulgation by MSHA.

## Selection of Mining Systems and Mine Opening Design

8. Coal Mine Single-Entry Study

Objective: To compare the structural stability and safety of single entries used as either double gates or single gates with that of double- or multiple-entry systems. Appropriate changes in or interpretations of the health and safety law will be recommended to MSHA, and guidelines will be provided for evaluating single-entry development plans.

9. Ground Control Exploration and Its Application to the Design of Underground Coal Mines

Objective: To test, evaluate, and demonstrate the Bureau's technology in mine design and site investigations in the development of new underground coal mines, and to develop correlations that relate ultrasonic energy transmission characteristics of mine rock to static design parameters and rock stress distributions. Both dynamic and static core analyses will be conducted on the cores obtained from exploration holes, and overcoring stress measurements will be made in the area of at least one new coal mine. An investigation of dynamic transmission characteristics will be included. The correlation between laboratory tests and engineering parameters necessary for mine design will be defined.

10. Determine Validity of Existing Proximity Criteria and Vibration-Scaling Law

Objective: To determine the validity of previously established damage criteria and vibration levels relative to the proximity of surface blasting operations and underground coal mine openings. A means of predicting safe distances between the two operations will be developed. Base conditions of the underground coal mine openings will be determined, and measurements will be taken following the detonation of controlled surface blasts. Following each detonation, the data will be evaluated and plotted. A plan for site-specific determination of coal mine proximity criteria will be established.

11. Operational Guidelines for Stress-Measurement Systems

Objective: To complete the establishment of the range of effectiveness for the vibrating-wire stress-measurement system. The physical conditions of the borehole environment, the gage materials, and the method of signal interpretation will be determined. The modifications to equipment and procedures needed to produce a stress-measurement system having the reproducible accuracy necessary to monitor ground control stress changes relative to mining will be defined. New designs will be field-tested and their performance will be compared with that of old gages.

12. Pillar Design Procedures for Thick Coal Seams

Objective: To identify the operational and design parameters that most affect the stability of thick coal pillar ribs, and to develop stable rib design criteria and demonstrate control measures for reducing and/or eliminating rib spalling. The borehole shear tester will be used to measure shear strength in the roof, floor, and coal in three coal mines having ribs more than 10 feet high. Stress profiles will be determined across two or more pillars in each mine using borehole pressure cells. The depths of the yield or failure zones developed in the pillar ribs will be determined from the stress profiles and by using cylindrical pressure cells to detect the changes in coal modulus in the yield zones due to yielding or crushing. The degree of sloughing or slabbing of ribs will be correlated with pillar heights and depths of the yield zones. The measured yield zone depths and stress distribution will be compared with those predicted by using the borehole strength data in conjunction with various pillar design procedures. The reliability of these design procedures will be evaluated, and any correlations established between rib slabbing and both pillar height and yield zone parameters will be described.

13. Design of Longwall Development Entries

Objective: To develop guidelines and design procedures for evaluating the relative ground control merits of two-entry as compared to three-entry development systems for longwalls, given the structural properties of the coal and surrounding strata. The ground control performance of both two- and three-entry development systems used with longwall panels at an underground mine will be measured, as will pertinent physical and structural properties of the coal, roof, and floor strata. Structural analysis techniques will be used to analyze the results for the purpose of developing general evaluation and design guidelines for use in judging the relative merits of two- and three-entry development systems for longwall panels. The effect of soft floors on entry piller stability will be determined. Longwall face convergence and face abutment pressures will be measured in order to assess their effect on entry performance. The stability of the chain pillars will be evaluated, as will that of the rows of cribs flanking the chain pillars left after the longwall panels are mined in order to maintain ventilation through the gob.

14. Prediction and Control of Rock Bursts and Failures in Mines

Objective: To continue studies at the Galena mine for identification of methods for reliably predicting rockbursts. The 285 vein will be continually monitored to detect development of anomalous zones within active stopes on the vein. Location, spectral characteristics, and energy content of individual microseismic events will be determined. When the most efficient analysis techniques have been identified, new equipment will be incorporated into that already existing. Laboratory testing of the predictive capabilities of the scale-invariant theory of failure will be continued. Other possible events precursory to rock failure will be reviewed. Guidelines for rockburst prediction will be developed in establishing MSHA standards for burst prediction and control.

15. Pillar Destressing in Advance of Mining

Objective: To demonstrate that destressing potential rock burst areas in advance of mining will prevent rock bursts and create a safer working environment. Cap load cells, backfill pressure gates, and vein wall closure gages will be installed in the last 100 feet of a stope. The sill pillar on the 7,500 level above Nos. 10 and 7 stope will be instrumented. Bureau personnel will participate in technical meetings with mine and MSHA personnel to discuss final results of destressing work. Four seismograph stations will be maintained, and statiestical data will be gathered from their records.

16. Inherently Safe Mining Methods for Rock Bursts

Objective: To demonstrate an underhand mining method that can replace the currently used cut-and-fill mining method and determine the rock burst potential for the inherently safe mining method. A 3-year detailed plan will be developed, a demonstration site will be located, appropriate cost-sharing agreements will be negotiated, and an instrumentation plan will be prepared. Engineering study of the underhand method will continue to examine alternate or specific techniques needed for the demonstration.

## Roof Support Systems

17. Design of Haulage Drift Supports in Block Cave Operations

Objective: To design and test a drift support for block-cave mining that is safer than the present steel sets and monolithic concrete. An instrumented test section at a block-cave mine in the Southwestern United States will be monitored and evaluated. Based on the performance of the test support system, a longer test section will be designed and installed. Performance of the new support will be compared with that of conventional systems.

18. Inorganic Grouts for Coal Mine Roof Bolts

Objective: To design an effective system for installing inorganic, cement-grouted coal mine roof bolts. Designs will be prepared for installation systems using slurry to be mixed and ready for use in one minute.

Effectiveness of the existing installation system using cartridges consisting of cement and water microcapsules will be established by field trials in coal mines throughout the United States. Acceptance criteria for both the materials and the finished product will be prepared, and guidelines for the use of inorganic bolt systems will be outlined.

19. Concrete Crib Design and Field Testing

Objective: To select the most practical crib design for handling behavior, cost, and previous application to variable conditions with reference to project work. Concrete cribs will be redesigned to eliminate wire fiber and chambered cross-section, using lightweight, latex-based, portland cement concrete and yet preserving the original mechanical system properties. Tests will be conducted to determine scaling formulas and stiffness. One full-scale crib will be tested to destruction, and stiffness, load capacity, and failure mode will be determined. Cribs will be installed and monitored in various field applications.

20. Inmine Assessment of Longwall Entry Road Roof Support Load Characteristics

Objective: To define, through full-scale underground testing, the support loadings and strata activities associated with each of the loading situations encountered by gate road supports in longwall mines. Based upon the load history of various support systems, design criteria will be established for entry load permanent roof support systems. Analyze an initial panel and locate cooperators in different geologic settings. An interim report will detail instrumentation rational and group character together with support load history for at least one roadway.

21. Modeling Roof Bolting Systems

Objective: To develop statistically justifiable guidelines for roof reinforcement using mechanically anchored bolts, fully-grouted bolts, and friction stabilizers. The field conditions best suited for each method will be compared and described. Construction of the full-scale, roof bolt model system will be monitored, shakedown tests will be conducted, and operating procedures will be established. Plans for test rig utilization will be initiated, milestone charts will be prepared, and prioritization guidelines will be established for the test program, for both full-scale and one-quarter-scale trials. Analytical structural methodology for test rig data utilization will be established.

22. Utilization of Debondable, Tensioned, and Point-Anchored Resin Roof Bolts

Objective: To determine the support characteristics of debondable, tensioned, and point-anchored resin bolt systems. Criteria for use in making recommendations for bolting systems selection will be developed and cataloged. The literature will be reviewed, and the state-of-the-art for these bolt systems will be defined. A laboratory test program will be conducted to define each system's support characteristics under known and controlled conditions. Correlations between bolt types and host rock conditions as to support capability will be determined. Reports on each system will illustrate test programs and possible applications to specific ground support problem areas.

## Safe Support Installation and Protection at the Face

### 23. Inorganic Grouts for Roof Bolts

Objective: To develop and field-test two practical systems for installing fully grouted roof bolts with inorganic grouts in metal mines. The cartridge and the mix-extrude methods will be laboratory and mine tested. The best water-to-cement ratio for the cartridge will be tested in three mines, at least one of which will be a uranium mine in soft sandstone. The equipment will be modified and improved from the experience gained through the mine test.

### 24. Retreat Mining Methods

Objective: To review and coordinate the results of existing retreat mining contracts. Background and field studies will be conducted on current retreat mining systems in coal, metal, and nonmetal mines, and the findings will be incorporated with computer simulation results of various retreat support systems to identify those research areas in retreat mining where a high probability of success might be realized. The various health and safety and production statistics associated with retreat mining will be defined more accurately. The underground materials handling simulator will be applied to the retreat mining support system previously developed, and information gained will be collated into a basis for an expanded program in retreat mining methods.

### 25. Evaluate the Stability of Support Wall Systems

Objective: To determine the stability characteristics of various packwall materials and pack systems (in place). Work will include determining standardized tests required to establish materials characteristics, developing test program guidelines to determine the overall performance ranges of a pack, and establishing the procedures, by laboratory and inmine trials, necessary for MSHA to evaluate pack competence.

### 26. Analysis of the Effects of Cyclic Mine Roof Loadings

Objective: To determine the effects of cyclic loadings on both supported and unsupported coal mine roof when mining by different systems and machine types, and to establish the critical parameters of cyclic loadings necessary to insure the miners' safety for given geologic locations and mining methods. Roof-loading equipment that loads roof cyclicly will be surveyed. Other work will include defining ranges of cyclic loads, devising test procedures to monitor roof responses, designing and constructing test equipment, and performing initial tests underground in mines utilizing available cyclic loading equipment including mobile roof shields, retreat mining support systems, temporary face support systems, and entry support systems. An interim report will outline equipment that is cyclic, test instrumentation, and procedures, and give future program plans with milestones for full-scale, inmine tests.

## Hazard Detection and Monitoring Systems

### 27. Automatic Roof Failure Warning System

Objective: To develop a commerically practical roof fall warning system that will provide sufficient warning to insure that mine personnel are not in failure areas when roof falls occur. Field testing of prototype units will continue, and a performance base using natural small-scale roof falls as input data will be established. Field trials will be extended to mines in different geological provinces. Interim threshold levels for statistically justifiable warning indication limits will be defined. Guidelines for MSHA evaluation of system effectiveness will be initiated.

### 28. Laboratory and Field Study of Roof Failure Prediction in Mines

Objective: To more accurately predict the time of roof failure in coal mines. First, the causes of the time variation of phenomena precursory to fracture, for example, microseismic noise and tilt anomalies, will be determined in the laboratory. Second, this knowledge will be applied in the mine. The knowledge gained in laboratory experiments previously conducted to determine the cause of microseismic noise increase and decrease will be applied in the roof bolt test facility by monitoring and recording microseismic signals from a small array of geophones. The signals will be analyzed for frequency and amplitude changes on microseismic noise precursor thresholds. Plans for field verifications will be prepared.

### 29. Microseismic Monitoring of Coal Mine Entry Systems

Objective: To monitor microseismic activity in entries of an active longwall mine to determine the relative stability between double and single entries as tailgates for a retreating system. Using the data, the stability of the abutment pillar relative to encroachment of final mining will be determined, and the relationship of noise rate and magnitudes to failure zones, mining cycle, extraction rate, subsidence, and geologic conditions will be defined. Monitoring of microseismic activity at an advancing longwall site will continue, and data will be related to stress-buildup areas. The utilization of microseismic networks for mine system evaluation will be demonstrated to industry.

### 30. Coal Mine Bounce and Outburst Studies

Objective: To establish the reliability of the microseismic system and its components and finalize this system. Full-time monitoring will continue at field sites to provide sufficient failure data to characterize the mechanics of individual coal mine bounce and outbursts to aid in more effective formulation of failure control methods. Existing control methods will be tested and evaluated. Guidelines for monitoring and preventing coal bounce and outburst phenomena will be developed.

31. Thermal Detection and Prediction of Coal Bumps

Objective: To detect incipient coal bumps using measured temperature changes caused by increased stress, develop inexpensive techniques for coal bump detection using readily available equipment, and determine the physical and thermal properties of rock types to aid in field site selection and insure viability of investigative techniques. Laboratory tests will be performed on representative rock samples to measure properties necessary for successful completion of the study (diffusivity, conductivity, thermal coefficients, compressive strengths, tensile strength, etc.). A site will be selected for a full-scale test. If progress warrants, instrumentation will be installed to measure temperatures and temperature changes in potential "bump" locations.

32. Application of Rock Burst Technology

Objective: To determine destressing effects and effectiveness in an active mining structure by analyzing stress changes as seen from shifting rock noise activity. The prediction potential will be established by analyzing microseismic data from rock bursts. A fixed set of conclusions and results will be developed to be used in determining if further work is necessary. A mathematical model will be developed to aid in selecting instrument locations, and laboratory testing of deep mine rock samples will be conducted. A site will be selected for full-scale testing. The automatic rock burst monitor will be configured, proof-of-rock-burst guidelines will be provided for industry for both prediction and control of rock bursts.

33. Slope Failure Detection

Objective: To complete development of equipment, procedures, and prediction methods for open pit mine slope failures. The effectiveness of the system will be demonstrated by field trials at active mines. Threshold limits will be established for detecting imminent slope and toe failure from existing microseismic criteria. The technical basis for establishing failure-warning indicator systems will be determined. Methods for controlling or preventing unstable slope failure will not be undertaken until after the warning system has been successfully demonstrated and accepted by industry.

34. Guidelines for Comprehensive Rock Burst Detection Plans

Objective: To summarize state-of-the-art methods, reliability, and costs of rock burst detection devices and schemes in a document for public distribution. Instrumentation used in post rock burst studies will be summarized. Equipment, techniques, data reduction, and interpretation will be described. Reliability of the various detection schemes will be discussed, and estimates of hardware cost will be given. It will be shown how each instrument or instrumentation scheme might be used in a comprehensive rock burst detection plan to comply with 30 CFR 57.3-35.

## Mine Waste Stability

35. Alternatives to Present Coal Waste Disposal Methods

Objective: To develop and demonstrate alternatives to present coal waste disposal methods that will result in safer and more environmentally acceptable disposal techniques. The survey started in fiscal year 1978 of eastern and western coal companies will be assessed as to environmental and other problems related to present disposal techniques. Laboratory equipment will be obtained, facilities to test samples for the most promising method or methods of sludge dewatering as determined under companion contract will be set up, and safety analysis of coal waste embankments will continue including comparison of centrifuge and various computer factors of safety, physical properties of coarse and fine coal waste mixtures, and preliminary liquefaction tests to determine mass flow rates.

36. Electrokinetic Consolidation of Coal Sludge

Objective: To demonstrate the technical and economic feasibility of electrokinetic dewatering of coal sludge to produce stable waste. An agreement will be concluded with a coal mine operator concerning conduct of the field test including the cooperator's level of involvement, site conditions, and sludge properties. Test equipment will be produced, and the test site will be prepared. After laboratory tests are conducted to optimize parameters, full-scale tests will be performed. A safety and procedures manual will be prepared for the benefit of industry and regulatory agencies who will utilize and regulate the applications of this technology.

37. Factor of Safety-Risk Analysis in Tailing Dam Design

Objective: To establish statistical techniques in order to define a level of uncertainty in stating the safety factor value for tailings dam design. Current computational techniques for computing safety factors will be reviewed, collated, and summarized. An outline for a companion contract to perform risk analyses will be prepared, as will a report outlining the statistical rationale for safety and risk analysis in tailings dam design.

## Industrial-Type Hazards

Program Objectives: To (1) limit the possibility of human error through training and worker-machine interfacing, (2) improve equipment design and controls, (3) detect and prevent failures of electric circuitry and hardware, (4) provide adequate lighting in working areas, (5) insure continuous and reliable communication between all underground and surface mine personnel, while providing continuous surveillance of the mine environment, and (6) improve safety in haulage and materials-handling operations.

## Human Factors

1. Standards for Mine Equipment Design

Objective: To assure adequate in-house capabilities in the development and implementation of human-factor-type research programs. Investigations and evaluations of new equipment and/or training devices will be accomplished under this program. This will entail the technical evaluation of unsolicited proposals, preparation of requests for proposals, and in-house support of cooperative agreements to evaluate and demonstrate research equipment. Specifically, field demonstrations of the roof bolter training system will be supported by this project.

2. Identify Safety Advantages of the Blind Shaft Borer Compared to Conventional Shaft Sinking

Objective: To identify advantages of the blind shaft borer (BSB) compared with conventional shaft sinking, provide estimates of lost-time accident reduction expected from use of the BSB, implement designs to enhance system safety, and review possible changes to MSHA regulations that will permit better system performance and not compromise safety.

## Electrical

3. Electrical Equipment Devices and Systems

Objective: To evaluate commercially available devices and techniques for inspection, fault locating, and protection of electric power systems for applicability to mining. Laboratory and field tests of apparatus and methods developed under contract, including cable fault locaters, will be conducted. Novel approaches to mining electrical problems will be developed. Sessions including hands-on experience with selected devices and techniques will be conducted for coal mining personnel.

## Equipment

4. Equipment Development

Objective: To modify and equip the rail test track at the Pittsburgh Mining and Safety Research Center to evaluate automatic emergency brakes for rail haulage cars. Brakes developed through a contract effort will be installed and evaluated. Several types of couplers will be fitted to the rail haulage cars and tested.

5. Hazard Analysis, Program Development, MSHA Impact on Research, and Remote Operation of Surface Equipment

Objective: To develop a data base that will provide information on equipment size, reliability, use, and capability to aid in establishing safety criteria or identifying safety problems in different types of surface mining operations. The technical aspects and safety of new or modified surface mining

equipment will be evaluated. All new MSHA and Occupational Safety and Health Administration regulations that may impact the industrial-type hazards research and development program will be reviewed. Remote operation of surface equipment will be evaluated.

6. Feasibility of a Buried-Line Detector for Earthmoving Equipment

Objective: Determine the feasibility of developing a buried-line detector that will warn a heavy equipment operator when he is near a buried pipeline. This will reduce the possibility of an explosion, fire, or both, when a natural gas or other pipeline is encountered in surface mining operations and excavations.

7. Inmine Testing of Collision Protection Systems for Large Mining Equipment

Objective: Develop prototype hardware that will reduce the vehicle collision hazard in open pit mines. The prototype hardware will be inmine-tested to develop the ruggedization necessary to insure the instrumentation will withstand the mining environment. This hardware will help to offset the driver's reduced field of vision, which decreases as mining equipment gets larger, causing many of the collisions.

## Illumination

8. Mine Illumination

Objective: To evaluate specialized power supplies required to light mining equipment that is energized by sources other than alternating current or 300-volt direct current. The machine-mounted permissible illumination systems in use in the Safety Research Coal Mine at Bruceton will be maintained and updated. The implementation of computer simulations to photometrically evaluate mine illumination systems will continue, and methods for implementing proposed standards for lighting surface mining equipment will be investigated.

## Nonemergency Communications

9. Develop Underground Communications Systems

Objective: To develop and field-evaluate special systems and hardware for the purpose of improving inmine and surface-to-underground communications. Special mine communication problems will be analyzed, special requirements will be established, systems will be designed, hardware will be procured and modified, and hardware and composite systems will be laboratory-evaluated. Acceptable systems will be evaluated in the Bruceton mine and/or an operating mine.

10. Mine Telemetry and Surveillance Systems (Coal)

Objective: To design the hardware and software for a single remote-monitoring station, to design a contral station and its required program, and to test the combination in a single remote station configuration before constructing or acquiring a multistation system.

11. Mine Telemetry and Surveillance System (Metal and Nonmetal)

Objective: To integrate newly available telemetry and late development sensors for CO and air velocity into an environmental monitoring system. This system will be installed in a metal or nonmetal mine, primarily to detect fire from changes in CO level but also to monitor CO levels where diesel-powered equipment is used. This will be done in conjunction with an architectural and engineering contractor.

Haulage and Materials Handling

12. Fatigue Testing of Wire Rope With Independent Wire Rope Core--Pneumatic Transport Safety Study

Objective: To build a wire rope fatigue-testing machine and conduct fatigue tests that can be used as a basis for wire rope retirement criteria. Fatigue tests will be conducted on wire rope to determine rope life at different loads and to determine when appropriate safety factors have been met. Recommendations on retirement criteria will be made on the basis of fatigue tests. Also, a preliminary design will be prepared of a pneumatic system for transporting coal from a continuous miner to the mainline haulage or to the surface through a borehole.

13. Materials Handling Equipment Development

Objective: To investigate methods by which various facets of mine materials handling activities can be made less labor intensive. Particular areas of interest will be the transfer and handling of machine components during maintenance activities, the handling of fall debris, and research in support of contractual efforts. Prototype devices to minimize the handling of underground supplies will be designed, constructed, and evaluated in operating mines.

14. Portable Hydraulic Steering for Large Haulage Vehicles--Driver Alertness Monitoring

Objective: To evaluate the problem and then design, fabricate, and inmine-test a portable hydraulic system prototype for steering one specific type of large haulage vehicle. This system will consist of a hydraulic pump that is powered by a small gasoline or diesel engine. Connections to the vehicle will be made to the main hydraulic reservoir and high-pressure side of the steering circuit through quick-disconnect couplings. This self-contained unit will be compact and light enough to be carried by one or two men. Investigation of adapting off-the-shelf sleep monitors to monitor drivers of large haulage vehicles will continue.

Postdisaster

Program Objectives: To develop technology that will (1) enable survivors of a mine disaster to escape from the mine or to continue to survive while awaiting rescue by providing protection against toxic and/or oxygen-deficient

atmospheres, (2) aid in the location of miners trapped underground, using seismic and electromagnetic means of communications, and (3) facilitate post-disaster rescue and recovery operations through surface monitoring of conditions underground, emergency communications, and mechanized transport of life support equipment for mine reentry and rescue operations.

### Survival

1. Development of Life Support Technology

Objective: To investigate, evaluate, and develop advance life support technology for use in coal mines for self-rescue and rescue team operations. Concepts for design of low-profile rescue-breathing apparatus will be examined. Available breathing apparatus will be tested in the automated breathing metabolic simulator (ABMS). Escape speeds and metabolic requirements in various coal mines will be evaluated.

### Communications

2. Develop Borehole Instrument Package for Postdisaster Surveillance

Objective: To complete low-level-light television (LLLTV), solid state television (SSTV), and infrared (IR) probes. Probe components will be modularized to enable a composite probe to be assembled for a specific situation, and all probe systems will be integrated to minimize redundant equipment.

3. Trapped Mine Location and Communication

Objective: To develop a variety of packaging schemes for the trapped miner, ultra-low-frequency system; to determine optimum antenna parameters using the most recent propagation data; and to investigate advanced concepts for use in highly conductive strata, including use of extremely low frequency (30 to 300 Hz) systems.

## Systems Engineering

Program Objectives: To operate and maintain underground research and test facilities for use in testing and demonstrating new procedures and equipment before they are field-tested in commercial mines. To participate in contract development and in the formulation of mine health and safety standards.

### Test Facilities

1. Operation of the Experimental Mine and Safety Research Coal Mine

Objective: To maintain and operate the two mine facilities at Bruceton which are used for coal mine health and safety research problems. The underground mines must be maintained in safe and proper operating condition in order to conduct full-scale experiments on explosives, dust suppression, roof control, ventilation, fire and explosion prevention and suppression, haulage safety, communications, mine surveillance, and many other facets of coal mine health and safety research.

2. Supervision of Jenny Mine

Objective: To provide an onsite mine manager to coordinate all activities at the Jenny mine during the renovation and conversion of the mine to an underground test facility for fires and explosion research.

Systems Analysis

3. Economics of the Application of Improved Health and Safety Hardware in the Mining Industry--Automatic Truck Fire Protection System as a Case Example

Objective: To identify the criteria used by the mining industry in its adoption of Bureau-developed health and safety hardware improvements, using the automatic truck fire protection system as a case example. Criteria will be identified by making an extensive literature search and through personal contacts with mine owners, operators, safety personnel, equipment manufacturers, MSHA officials, and insurance companies. These criteria will be analyzed so that future Bureau-developed technology can be transferred to industry in a timely manner.

Explosives

Program Objectives: To assess the problems associated with the safe and effective use of explosives in all types of mining activity; these include fixed explosives, blasting agents, blasting devices, and blasting accessories. To conduct fundamental studies of explosive behavior and apply the results in the development of new technology. To develop new and improved test procedures as new mining methods are introduced and new types of explosives are formulated.

Blasting Agents and Other Hazardous Chemicals

1. Permissible Explosive Evaluation and Research

Objective: To explore and resolve problems associated with safe and effective use of underground coal mine explosives in gassy and dusty mines. The research program will include a study of the causes of misfires and deflagrations occasionally reported for permissible water gels. New formulations prepared by other Bureau personnel will be tested in the gallery; this supportive work is part of an effort to reduce the incendivity of water gels with chemical additives. Work will include testing new permissibles, field samples, and explosives involved in mine incidents.

2. Development of New Schedule Tests and Standards

Objective: To develop standards for permissible explosives, explosive devices, and blasting accessories, and to develop test procedures and basic knowledge of explosive incendivity in support of the standards. Schedules and related tests will be developed for stemming devices and other explosive-actuated devices. The problems of (1) desensitization of water gel explosives by extreme temperatures and (2) dynamic desensitization leading to misfires

will be investigated. In addition, the mechanisms of ignition of flammable atmospheres by shot firing will be investigated.

3. Hazards of Explosives and Explosive Devices

Objective: To produce data, supply information, and make recommendations relating to the sensitivity of explosives and initiating devices to impact, friction, thermal, and electrostatic stimuli. Optimum designs for antielectrostatic devices for electric detonators will be developed. Research for an ultrasafe detonator will continue, applying results of antielectrostatic studies and incendivity studies from related projects. Sensitivity tests will be conducted in connection with investigations of misfire accidents.

4. Fire Hazards of Explosives and Blasting Agents

Objective: To produce data in support of the development of standards for the storage and handling of explosives and blasting agents. Large-scale (field) burning tests of explosives and blasting agents will be conducted, based on information gathered from laboratory experiments. Laboratory-scale determinations of ignitibility, burning rate, sensitization at elevated temperatures, and tendency to detonate during combustion will be continued for these explosives. Laboratory and field test results will be correlated, in order to provide a set of test procedures and standards for determining tendency to detonate.

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